A Guide for Teachers

Dream, Invent, Create a Career in Engineering

Get kids excited about a career in engineering. Fun lessons, guidance and insights about engineering learning and careers, and the support educators need to make it all work for elementary-level students.

Start Engineering

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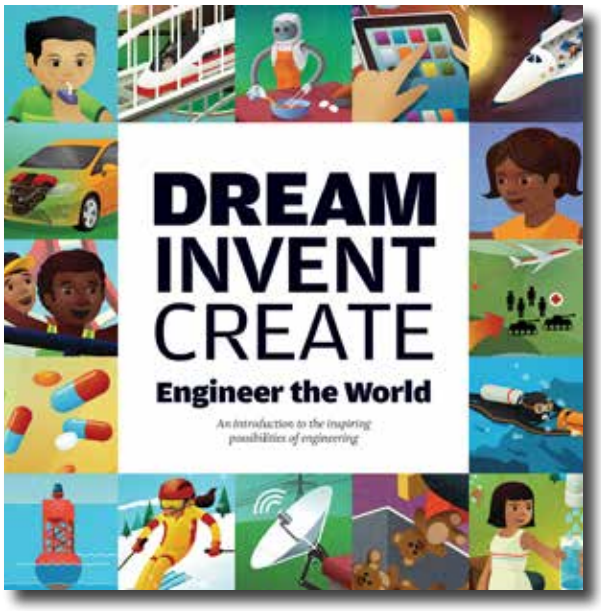
Using This Guide

"WHEN DO WE GET TO BE ENGINEERS AGAIN?" is not something you hear every day from second-graders. But when Woodland Elementary School in Ohio completed a grade-wide engineering unit, that is the question teachers reported hearing for weeks afterward.

Career awareness might seem out of place in elementary school, but students at this age — like the Woodland kids — are already starting to try on possible careers in name and deed. And not a moment too soon, really; "career readiness" requirements are being written into state learning standards all across the country. For this reason, educators at all K-12 levels need to find fun, learning-rich content to align kids' intrinsic interests with career-oriented classroom activities.



This guide accompanies Start Engineering's **Dream, Invent, Create** (a National Science Teachers Association Recommends publication) and can help elementary educators incorporate career awareness activities into the classroom. Overall, engineering jobs are projected to increase by over eight percent in the coming decade, significantly above overall job growth, according to the Bureau of Labor Statistics. We have picked out four engineering fields with great prospects for not only future career opportunities but also personal satisfaction. Biomedical, computer, electrical, and environmental engineering all promise not only innovations that will shape our future but also career prospects to entice all kinds of students. Educators will find substantive descriptions of these engineering fields in each section, with plenty of material to round out students' understanding of what professionals in each field can do.

Using This Guide (continued)

Elementary-level career awareness activities often focus on questions of how and why people choose the careers they do. A goal of these activities is to guide students in exploring and understanding their own particular abilities and interests and then to connect them to possible career pathways.

With the goal of encouraging students to try on a potential "career identity" as an engineer, each section includes:

- A learning exercise, in both basic and advanced forms, to show students what the field is all about.
- Career reflection exercises to help students identify and assess interests and skills that might point them to a career in the field.

TEACHING A BASIC LESSON

The first two pages of each section prepare teachers to:

- Read the text with students.
- Review new vocabulary words.
- Discuss the "thought questions" provided to explore with students what a field of engineering is all about and what it might be like to work in it.

TEACHING AN ADVANCED LESSON

After the introductory material, each section presents a full, "advanced" lesson.

The activities prepare teachers to:

- Summarize the activity.
- Explain the link to the specific area of engineering.
- Guide a warm-up discussion.
- Lead the lesson, including:
  - → Pose questions to students.
  - → Present the topic.

Using This Guide (continued)

- → Show how to use materials.
- → Review the results of students' work.

Engage students, using the Career Reflection Worksheet, in activities and discussions about the field as a prospective career pathway for them.

Throughout this guide, we present information in different ways to help educators build students' career awareness of engineering. In one way, we present background information about engineering meant to explain the field to educators. In another way, we offer text that educators can read aloud, either word for word or adapted in an age-appropriate tone for sharing with students.

Such "**read-aloud**" text is accompanied by the symbol at right. READ ALOUD

Please let us know what you think! To purchase **Dream, Invent, Create** for your classroom, please go to: start-engineering.com/shop

Congratulations! You are now ready to start teaching engineering and helping students figure out if engineering might be the right career for them!

Why a Career in Engineering?

Engineering is a great career for people who want to make the world a better place, learn and grow and experience new things at work, and earn the rewards that come from doing important, challenging things. Read on for big ideas to share with students about why a career in engineering could be right for them.

READ ALOUD

Engineering shapes the future.
Engineering is how dreams about the future become the future we actually live in. From wind turbines that reduce pollution to new wonder drugs to safety in cyberspace, engineering is the key to solving society's grand challenges.

Engineering makes our lives cooler and more fun!
Roller coasters, video games, phone apps, and who knows what else is to come — it all takes engineering to be made real.

Engineering delivers rewards of many kinds.
It's a path to success in nearly every field, with jobs and opportunity available to all who can do the work. Salaries start higher than nearly any other college major.

Why a Career in Engineering? (continued)

READ ALOUD

Engineers use creativity to solve problems.

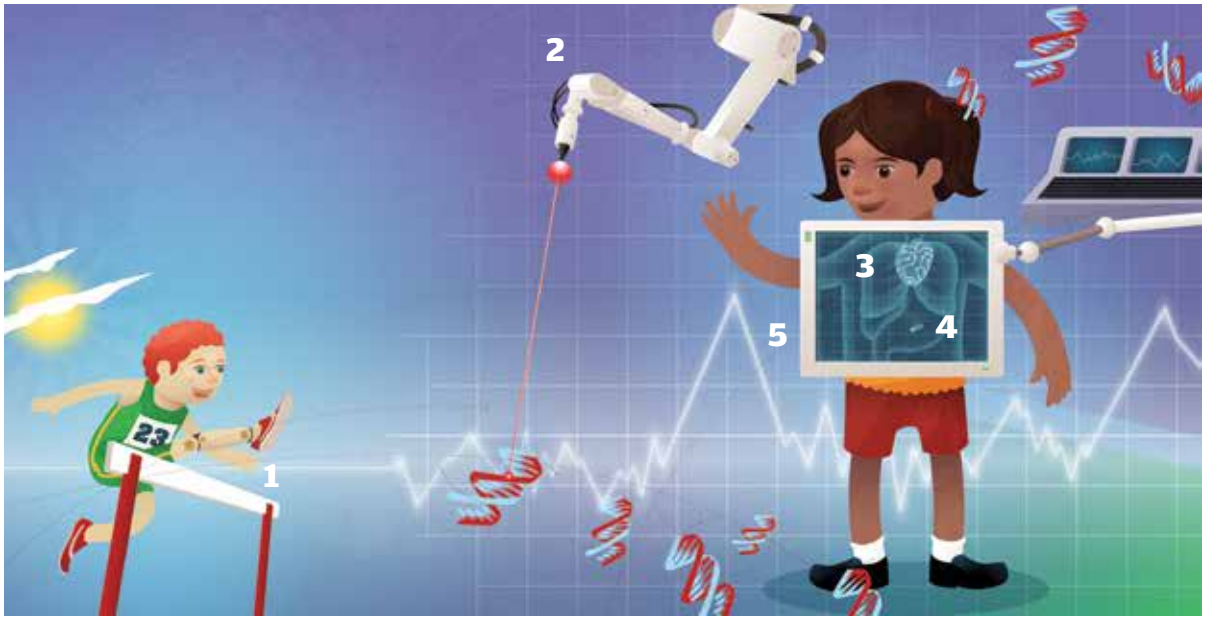
Engineers build tunnels through mountains of rock and sound systems for rock stars. They brew cleaner fuel for our cars, help athletes perform at their peak, and design computer systems for us to buy shoes, books, or almost anything with a simple tap on a screen.

Engineers make a world of difference.

Scientists study the world as it is. Engineers imagine the world as it could be. From a rip-resistant garbage bag to a Mars-bound rocket, they figure out how to deliver what people need or want – all within the constraints of time, money, and the laws of nature.

Engineers bring our days to life.

From the time we wake up to when we fall asleep, engineers give shape to our days. Watches that measure our sleep and wake us at just the right time, breakfast cereals made from disease-resistant grains, timed traffic lights on the way to school or work, and all the other devices and systems that help us get the most out of the day – engineers make them all possible.



BIOMEDICAL ENGINEERING

TEACH THE BASIC LEARNING EXERCISE

STEP 1 → Ask the students to turn to page 8 of "Dream, Invent, Create" and then read the rhyme aloud to the class. Or ask 3 different students to each read a stanza.

STEP 2 → Explain that this page is all about **biomedical engineering**, and read the text around the border, which is also written out on the next page of this guide.

STEP 3 → Introduce the vocabulary from the biomedical pages, by pointing out each image on the illustration. The numbers on the illustration correspond to the vocabulary on the next page of this guide.

STEP 4 → Then, start a Classroom Discussion (page 11), either verbally or as part of written assignment using the Student Workbook.

STEP 2: READ ALOUD THE TEXT AROUND THE BORDER

READ ALOUD

SO COOL Biomedical engineers design, build, and test technologies that doctors can use to diagnose and treat patients.

WHAT ELSE? They design prosthetics so athletes who have lost a limb can still run, jump, and swim.

NEW STUFF Biomedical engineers are designing surgical tools to make operations quicker and more precise, and working on new types of scanners to see what happens in the brain.

TELL ME MORE They're building artificial organs like hearts, kidneys, and livers, and growing tissues like skin and bone.

STEP 3: DISCUSS THE VOCABULARY AND CONCEPTS

READ ALOUD

Point out each image on the illustration and match it with the vocabulary below:

1. **Prosthetic leg:** Some people may require replacement body parts. Those who need artificial legs must have a structurally stable one to replace a critical part of the skeletal system. One specialty of biomedical engineering is designing and creating new and better prostheses (replacement body parts). Biomedical engineers are continually improving the strength, durability, longevity, and lifelikeness of prostheses so amputees can lead full lives.

2. **Laser knife:** A laser is a light beam that can be focused on a very small area. Engineers have created lasers that offer surgeons the ability to operate very precisely on their patients. They can focus on a small area and damage less of the surrounding tissue. Patients who have laser therapy may experience less pain, swelling, and scarring than with traditional surgery.

3. **Artificial organ:** a man-made device that is implanted into a human to replace a natural organ (like a heart) so the patient may return to a normal life as soon as possible.

4. **Camera in a pill:** Thanks to biomedical engineers, doctors can now take a really close look at your digestive system: you swallow a tiny camera that's about the size of a large vitamin pill. The capsule contains lights to illuminate your digestive system, a camera to take images, and an antenna that sends those images to a recorder you wear on a belt.

5. **Medical scanner:** This device creates images of the inside of your body so doctors can figure out if something is wrong, and how to treat you.

ADDITIONAL VOCABULARY FROM THE LESSON

Biomimicry: Copying or imitating the special characteristics of naturally existing things (animals, plants, etc.) in human-made designs, products, and systems. From *bios*, meaning life, and *mimesis*, meaning to imitate.

TEACHER TIP: There are many examples on page 18 of this guide.

STEP 4: START A CLASSROOM DISCUSSION

This can be done either verbally in the classroom or as part of a written assignment using the worksheet in the Student Handbook.

1. Some doctors are now able to see and treat their patients by examining them through a camera on their phones or computers. What would be the advantages and disadvantages of this type of treatment? (Ability to treat patients in remote locations; diagnosis may not be as accurate as seeing a patient in person.)

2. What kinds of things do animals do better than humans? Is there anything we can learn from them? (Besides the ability to fly, swim and/or keep warm with their fur and feathers: some animals have a better sense of smell [top of the list: African elephant and rats!] and can hear things that humans cannot [nocturnal animals like moths, bats, and owls, but also your pet dog or cat!]. Crocodiles can go without food for up to two years; camels can go six to seven months without drinking water.)

4. Remember the last time you were at the doctor's office? What tools or instruments did the doctor use during your visit? These are all things a biomedical engineer would help design and make. Pick out one of those tools and imagine how you could make it work better or help doctors learn more about their patients. (For example, make needles smaller so they don't hurt, make blood pressure cuff noise less scary, develop a machine so doctors can scan you and know your height and weight right away.)

TEACH THE ADVANCED LEARNING EXERCISE

STEP 5 → After completing the basic learning exercise, use the introductory materials as read-aloud text or general background information to prepare students for the advanced exercise.

Do the **Biomimicry: Natural Designs** exercise with your students.

TEACH THE CAREER REFLECTION EXERCISE

STEP 6 → Read aloud and discuss the first two paragraphs together as a class.

Depending on your students' age or level of interest, share the information below about biomedical engineering careers:

- 10-year growth rate for biomedical engineering jobs: 7.0%
- 10-year growth rate for jobs overall: 3.7%
- Median salary, 2019: $91,410
- Median individual salary overall, 2019: $40,100

STEP 7 → Students complete the Career Reflection Worksheet, with answers to serve as materials for further class discussions, as appropriate and feasible.

TRY THE EXTENSION ACTIVITY

STEP 8 → Ask the students to pick any of the vocabulary words and create a poster or write an essay, or research a real-life biomedical engineer.

SOURCES: BUREAU OF LABOR STATISTICS, UNITED STATES CENSUS

STEP 5: BIOMEDICAL ENGINEERING ADVANCED EXERCISE

Biomimicry and Natural Designs

SUMMARY

Students learn about biomimicry and how engineers often imitate nature in the design of innovative new products. They demonstrate their knowledge of biomimicry by practicing brainstorming and designing a new product based on what they know about animals and nature.

ENGINEERING CONNECTION

Engineers often use the natural world as inspiration for design. Biologically inspired designs include air- and sea-going vessels, navigation tools such as sonar and radar, medical imaging devices, and biomedical technologies like prosthetics. Biomimicry has resulted in many creative products, such as a material inspired by the slick leaves of the lotus plant and its natural capacity to wash away dirt particles with every rainfall.

LEARNING OBJECTIVES

After this activity, students should be able to:

- Define biomimicry.
- Explain how engineers use biomimicry to design innovative new products.
- List examples of engineered products that were inspired by nature.
- Use biomimicry to develop an idea for a new product.

MATERIALS LIST

Each student needs:

- Paper
- Pencil
- Markers or colored pencils
- Ruler
- Construction paper
- Glue stick

READ ALOUD

WHAT IS BIOMIMICRY? Let's break down the word biomimicry into more understandable parts. "Bio" means life and "mimicry" means to imitate. So, biomimicry means to imitate life or nature. Biomimicry is a way of learning from nature. It is a way to observe nature in action and use that knowledge to inspire new ideas.

Engineers often use these ideas to develop cool new products or better ways to do things to help people. Today we are going to learn all about biomimicry and how engineers look at the amazing characteristics of animals and plants to create new or improved product designs.

Think of something that has been designed with nature in mind. How about Velcro®? Velcro® was invented after a man took a very close look at those little prickly seeds that stick to your clothing when you walk though a field.

READ ALOUD

Here are some more examples of inventions based on animals:

- Swimsuit, triathlon, and bobsled clothing fabric made with woven ribbing and texture to reduce drag while maintaining movement, mimics **shark's skin**.

- Radar and sonar navigation technology and medical imaging inspired by the echo-location abilities of **bats**.

- Super strong and waterproof silk fibers made without toxic chemicals by **spiders**.

- Glow sticks made with light-up chemicals, just like **fireflies**.

- A better ice pick for mountain climbers designed after the **woodpecker**.

- Adhesives for microelectronics and space applications inspired by the powerful adhesion abilities (stickiness) of **geckos and lizards**.

- High-speed bullet train made quieter by designing front like the **Kingfisher bird's bill**.

WARM-UP EXERCISE

Is It Biomimicry?

Give examples of design ideas, some that are biomimicry and some that are not. Have students vote whether or not they think the designs involve biomimicry. If the design does include biomimicry, ask for a volunteer to explain the natural world source of inspiration. Examples include:

- Airplane wing? (Answer: Yes, after bird wings.)
- iPhone? (Answer: No)
- Sonar navigation? (Answer: Yes, after bats.)
- Computer printer? (Answer: No)
- Hulls of submarines? (Answer: Yes, after dolphin and shark skins.)
- Soft cushion for a chair? (Answer: No)
- Solar cell? (Answer: Yes, after leaves.)

THE ENGINEERING DESIGN PROCESS

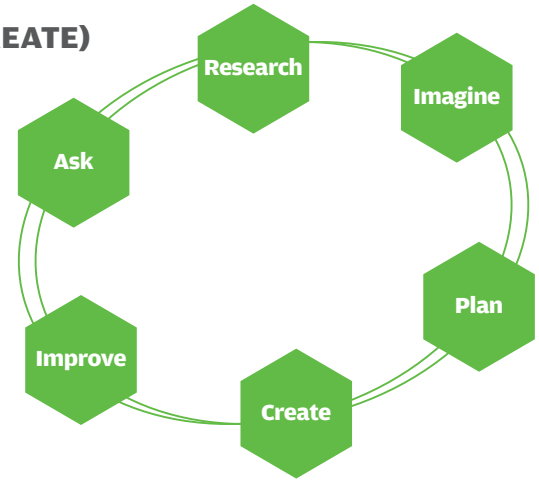
The engineering design process can serve as a template for critical thinking that will equip your students to find creative solutions to problems in any field, not just engineering. Engineering design is also central to "Next Generation Science Standards" and related science learning that a large majority of schools in the country have adopted over the last 10 years. This exercise explicitly combines engineering design with biomedical engineering content to illustrate how the two areas of learning can be taught together. The engineering design process, however, can be featured as part of any and all engineering exercises.

READ ALOUD

Today we're going to be engineers. When engineers create new inventions, the first solution is almost never the best one. To help engineers come up with new ideas, they use a process to make it easier. They brainstorm and test different ideas, learn from mistakes, and try again. By sticking to these steps, they can come up with new and exciting technology that changes how the world works. And the more ideas they try, the better the final answer ends up being.

Here are the basic steps:

- **Identify the problem (ASK)**
- **Research what has been used or done in the past (RESEARCH)**
- **Brainstorm possible solutions (IMAGINE)**
- **Design, build, and test a model (PLAN & CREATE)**
- **Use the test results to improve the model (IMPROVE)**
- **Keep testing and redesigning until the problem is solved** (process starts over)



Let's get started!

STUDENT EXERCISE USING ENGINEERING DESIGN PROCESS

1. Lead a discussion with the whole class about students' favorite animals. Identify about 8-10 different animals. Write the list somewhere in view of the class.

2. As a class, identify several distinctive features of each animal. Does it fly? Swim? Run fast? Is it furry, smooth, slippery? Does it have claws? Sharp or dull? How well does it see, hear, or sense things?

3. Ask the class what these animals can do that humans would like to do. This represents the **ASK** part of the engineering design process. (Dogs can smell and hear extremely well, cats can climb and always land on their feet, birds can fly, dolphins can swim and use echolocation, etc)

4. Ask students which of these animals' capabilities remind them of human-made products or tools or objects – or aspects of these things – that they use or know of. This is the **RESEARCH** part of the engineering design process. (What has already been done to give humans animal abilities? Submarine, planes, glow sticks, ice pick, examples from previous page.)

5. Divide class into small groups of students.

6. Have each group select an animal whose traits they wish they had. This is the **IMAGINE** step. (kangaroo legs, eagle eyes, alligator teeth, elephant trunk and ears.)

7. Ask students to think about how these abilities would be most useful if they could build them into a technology. Students should pick one trait that could improve an existing product and be useful or fun for people in some way. Now the students are at the **PLAN** stage. (Wings on a car, eagle eyes on an airplane, elephant trunk for your scooter to help you hold things as you go, boots with a "thumb" that work like monkey feet, skateboards with kangaroo-like jumping feature, monkey tail attached to pants so you hang from monkey bars, swimsuit with a shark fin on the back.)

8. Groups then draw their imagined, biomimicry-inspired product for sharing with the class. Each drawing should be accompanied by an explanation of how it is an example of biomimicry as well as an explanation of how it would benefit people. Explain that this is the **CREATE** stage.

9. What would be the obstacles to making this product work? How could the students make it better? Explain that this is the **IMPROVE** stage.

10. Groups then present their new invention to the class. The class can then debate or vote on which one they like best and explain why.

STEP 6: CAREER REFLECTION EXERCISE

Discuss Biomedical Engineering Careers

READ ALOUD

What do biomedical engineers do?

Biomedical engineers combine engineering principles with medical sciences to design and create equipment, devices, computer systems, and software.

Is this a good job?

A good job is one that you like to do and that connects with your skills, interests, and values. You should also think about what kind of need exists for people to do jobs that might appeal to you.

The need for biomedical engineers is expected to increase more than for most other jobs over the next ten years. And the typical salary for biomedical engineers is over two times higher than the typical salary for jobs overall. So if you like what you're learning about biomedical engineering, it might be a good job for you!

After doing the biomedical engineering lesson, read and answer the following questions. They serve as a guided exercise for you to identify and assess skills and interests of yours that might make biomedical engineering a good career for you.

STEP 7: CAREER REFLECTION EXERCISE

Start a Classroom Discussion

READ ALOUD

(Or have students complete the worksheet in Student Workbook)

1. Think about what it felt like doing a biomedical engineering exercise. What parts, if any, did you enjoy? What parts did you not enjoy?

2. What skills do you think you used in completing your exercise? Write down as many as you can think of (shoot for at least 5, like math, reading, collaboration, imagination, art, measurement, and so on).

3. Looking back at this list of skills, pick the three you think you're best at. Which are the three hardest for you? How important do you think these skills would be in biomedical engineering? Why?

4. Can you think of anything you have seen or used or learned about that could have been designed by a biomedical engineer? What was it? How did it work? How can you imagine making it work better?

5. On a scale of 1-5, how much do you think you would like being a biomedical engineer, with 1 being a hole in the head and 5 being like cupcakes?

COMPUTER ENGINEERING

TEACH THE BASIC LEARNING EXERCISE

STEP 1 → Ask the students to turn to page 14 of "Dream, Invent, Create" and then read the rhyme aloud to the class. Or ask 3 different students to each read a stanza.

STEP 2 → Explain that this page is all about **computer engineering**, and read the text around the border, which is also written out on the next page of this guide.

STEP 3 → Introduce the vocabulary from the computer pages, by pointing out each image on the illustration. The numbers on the illustration correspond to the vocabulary on the next page of this guide.

STEP 4 → Then, start a Classroom Discussion (page 25), either verbally or as part of written assignment using the Student Workbook.

STEP 2: READ ALOUD THE TEXT AROUND THE BORDER

READ ALOUD

SO COOL Computer engineers design the software and hardware for computers, smartphones, and other electronic gadgets we use today.

WHAT ELSE? They often combine what they know about electrical engineering and computer science in their jobs.

NEW STUFF Computer engineers helped to design your favorite video game system or social media website.

TELL ME MORE They might also help set up computer networks, develop software to control robots, and create new ways to share digital music.

STEP 3: DISCUSS THE VOCABULARY AND CONCEPTS

READ ALOUD

Point out each image on the illustration and match it with the vocabulary below:

1. Video games: Computer engineers make games for any kind of device.

2. Cybersecurity: Protecting software and hardware from theft or damage, as well as from disruption of the services they provide.

3. Phones & tablets: Computer engineers are involved in making not only computers, but also hand-held devices like phones and tablets.

4. 3-D movie graphics: Movie and gaming companies hire computer engineers to make their ideas come to life.

5. Gadgets: Computer engineers also help develop futuristic devices like the smart watches and VR game consoles.

ADDITIONAL VOCABULARY FROM THE LESSON

Software: The programs, apps, social media, and games we run on our computers and devices.

Hardware: Computers, phones, tablets, electronic watches.

Computer network: Also known as a local area network (LAN), it's a network that connects computers and devices in a limited geographical area such as a home, school, office building, or closely positioned group of buildings.

Algorithm: A series of instructions on how to accomplish a task that computers follow.

Coding: Transforming actions into a symbolic language for a computer.

Debugging: Finding and fixing issues in code.

Function: A piece of code that can be called over and over.

Parameters: Extra bits of information that you can pass into a function to customize it.

STEP 4: START A CLASSROOM DISCUSSION

This can be done either verbally in the classroom or as part of a written assignment using the worksheet in the Student Handbook.

1. Do you play video games? What devices do you play them on? Which one is your favorite? Engineers designed all of them!

2. How do you think engineers could improve videos games? What kinds of things would make them more fun? (What makes a good game? What makes a bad game? Should they be more interactive? Have better graphics?)

3. What about phones and tablets, and any other gadgets? What do you wish they could do? (Have 3-D holographic displays; be able to fold into smaller devices; be more eco-friendly and recyclable; have longer battery life.)

TEACH THE ADVANCED LEARNING EXERCISE

STEP 5 → After completing the basic learning exercise, use the introductory materials as read-aloud text or general background information to prepare students for the advanced exercise.

Do the **Robotic Cups** exercise with your students.

TEACH THE CAREER REFLECTION EXERCISE

STEP 6 → Read aloud and discuss the first two paragraphs together as a class.

Depending on your students' age or level of interest, share the information below about computer engineering careers:

- 10-year growth rate for computer engineering jobs: 20.6%
- 10-year growth rate for jobs overall: 3.7%
- Median salary, 2019: $110,184
- Median individual salary overall, 2019: $40,100

STEP 7 → Students complete the Career Reflection Worksheet, with answers to serve as materials for further class discussions, as appropriate and feasible.

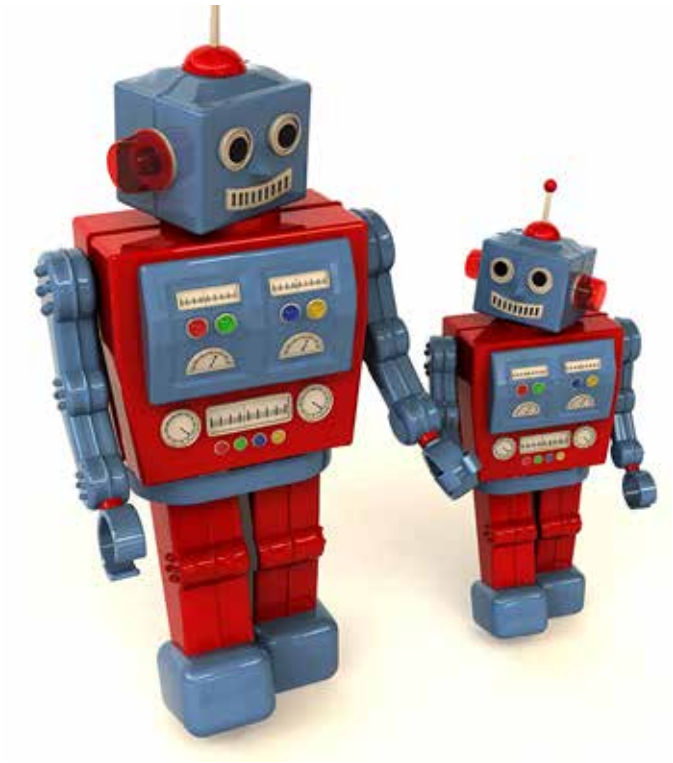
TRY THE EXTENSION ACTIVITY

STEP 8 → Ask the students to pick any of the vocabulary words and create a poster or write an essay, or research a real-life computer engineer.

SOURCES: BUREAU OF LABOR STATISTICS, UNITED STATES CENSUS

STEP 5: COMPUTER ENGINEERING ADVANCED EXERCISE

Robotic Cups



SUMMARY

Highlight programming techniques and illustrate the need for functions. Using a predefined "Robot Vocabulary" your students will figure out how to guide one another to accomplish specific tasks without discussing them first. This segment teaches students the connection between symbols and actions, as well as the valuable skill of debugging.

ENGINEERING CONNECTION

Programming resembles any exercise in engineering design; it involves developing, testing, and improving solutions to challenges.

LEARNING OBJECTIVES

After this activity, students should be able to:

- Learn to convert real-world activities into instructions.
- Gain practice coding instructions with symbols.
- Gain understanding of the need for precision in coding.
- Gain practice debugging malfunctioning code.

WHAT IS ROBOTICS?

READ ALOUD

Robotics is the field of designing, developing, and programming automated machines to do work for people. Has anyone heard of robotics? Has anyone seen a robot or touched one? Does a robot really "hear" you speak? Does it really "understand" what you say? The answer to the last question is: "Not the same way that a person does."

Robots operate off of "instructions," specific sets of things that they have been preprogrammed to do. In order to accomplish a task, a robot needs to have a series of instructions (sometimes called an algorithm) that it can run. Today, we are going to learn what it takes to make that happen.

MATERIALS LIST

Each student needs:

- Symbol key
- Cup tower sheet
- Disposable cups (6 or more per group)
- Blank paper or note cards (1 per person)
- Writing Instrument (1 per person)

PREPARATION

- Print and cut out Cup Stack Cards (pages 36-37).
- Print a Symbol Key for each group (page 38).
- Stack cups in designated area away from groups (Robot Library).

PROCEDURE

Hold up a copy of the symbol key (or write the symbols on the board). Step to the side and tell the class that these will be the only six symbols that they will be using for this exercise. For this task, they will instruct their "robot" to build a specific cup stack using only these arrows:

↑ Pick up cup

↓ Put down cup

→ Move ½ cup width forward

← Move ½ cup width backward

↻ Flip cup right 90°

↺ Flip cup left 90°

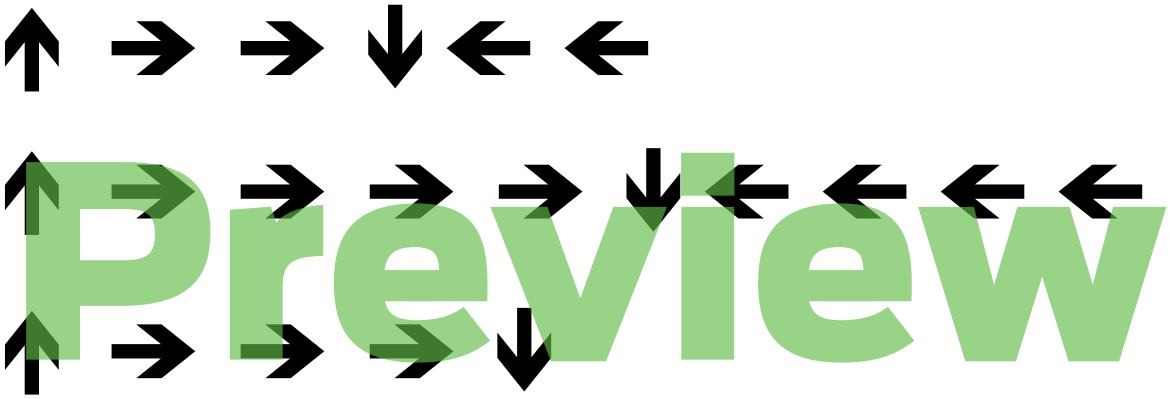
WARM-UP EXERCISE

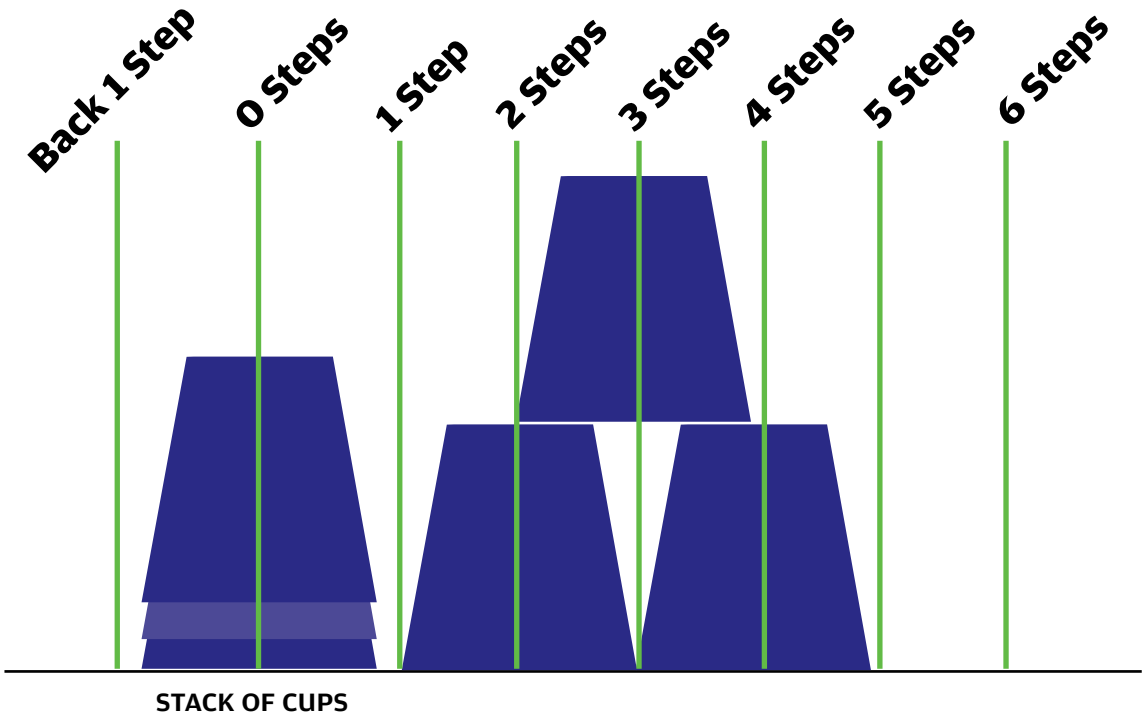
It can be helpful to go over an example as a class. There is one cup tower on the sheet that includes only three cups (see image at right); use this for the example. Hold it up for the class and walk them through the exercise.

Place your stack of cups on the table where everyone can see them. Tell them you'll be building the cup tower on the card. Ask the class to instruct you on the first thing to do. The correct answer is "pick up cup." When you pick up each cup, note that the cup should automatically rise above the highest cup already in the stack.

With your hand still in the air, ask for the next move. You may have to remind the class a time or two that one step forward is only half the width of a cup.

Once you've placed a single cup, transition back to the blackboard and challenge the class to help you write the symbols on the board so that you can "run the program" later. One possible solution looks like this:





With the program written down for the class to see, you can call a volunteer to "run" it, or you can run the program yourself. Say the arrows out loud as you move the cups into place. For example, the program above would be written out as:

Pick up cup, Step forward, Step forward, Put down cup, Step backward, Step backward

Pick up cup, Step forward, Step forward, Step forward, Step forward, Put down cup, Step backward, Step backward, Step backward, Step backward

Pick up cup, Step forward, Step forward, Step forward, Put down cup

ADJUSTMENTS

Grades K-3

- Try this lesson all together as one class. Let the students shout directions for the teacher to write down.
- Have a class assistant leave the room during programming, then return to perform the finished code.
- If there is time, switch. Have the assistant write the instructions from the class and have the teacher perform them.

Grades 4-6

- Adjust group sizes between three and five, depending on personality of class.
- Expect each student to want a turn, this will likely use the entire hour.

GUIDELINES FOR STUDENT EXERCISE

1. **GROUP UP:** Group the students appropriately for their age as described on page 34. The goal is to have enough programmers in each group that the group is never entirely lost.

2. **ROBOT:** Choose one "robot" in each group to go hang out in the "robot library." This should be a location far enough away from the groups that no robot can find out what Cup Stack Card their programmers are working with. Robots can use their time in the library to practice cup stacking and to ask for clarification on rules.

3. **PROGRAM:** Each group of programmers should be handed one Cup Stack Card at a time. They can then begin to figure out the algorithm for their stack. How many cups will they need? How many steps for the first cup? The second? Are any cups upside down? How do you get the robot to flip a cup?

4. Once these questions are answered, the programmers can use the symbols to write their code on the blank paper or a note card. The programmers should review their code to see if it makes sense for the stack before checking their robot out of the robot library.

5. **RUN CODE:** Now that the robot is back with the group, everyone should be silent. The groups should not attempt to use words or gestures to influence their robot's behavior. The robot should only operate according to what the arrows tell them to do.

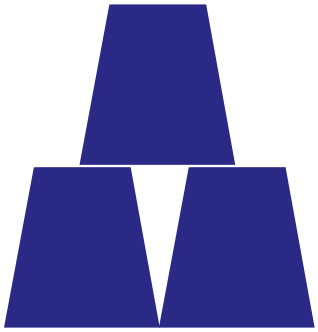
6. If the group finds a mistake, they are allowed to halt the program, check the robot back into the library, and fix the error before bringing the robot back to complete the challenge.

7. **REPEAT:** Each time a group solves a challenge, they should choose a new robot to head to the library, and the group should choose a new tower to build.

CUP STACK CARDS

Cut along the dotted lines to make enough Cup Stack Cards for each group in your class to get one. Groups can work on multiple versions of the same cup stack if you have more than 7 groups.

Students build these towers using the symbols (↑,↓,→,←, ↻,↺) as commands.



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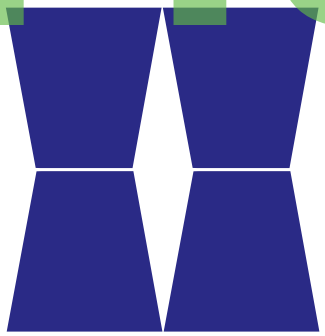

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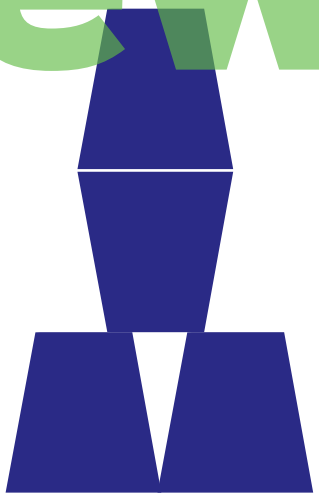

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CUP STACK CARDS

4

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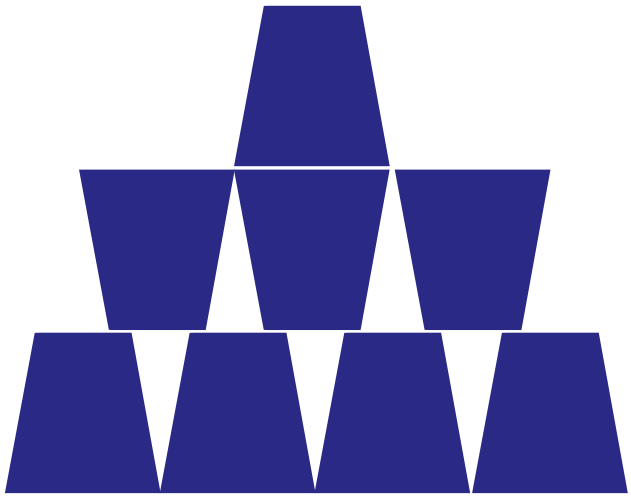

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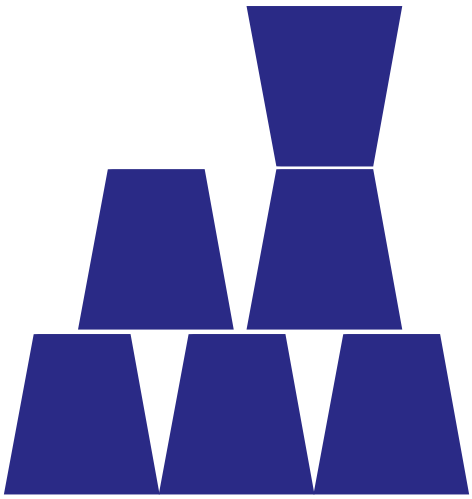


7

SYMBOL KEY SHEET

 Pick up cup

 Put down cup

 Move ½ cup width forward

 Move ½ cup width backward

 Flip cup right 90°

 Flip cup left 90°

STEP 6: CAREER REFLECTION EXERCISE READ ALOUD

Discuss Computer Engineering Careers

What do computer engineers do?

Computer engineers develop and design new software programs and hardware components, test programs and hardware, identify issues, provide solutions, and market software and hardware to possible buyers.

Is this a good job?

A good job is one that you like to do and that connects with your skills, interests, and values. You should also think about what kind of need exists for people to do jobs that might appeal to you.

The need for computer engineers is expected to increase notably more than for most other jobs over the next ten years. And the typical salary for computer engineers is almost three times higher than the typical salary for jobs overall. So if you like what you're learning about computer engineering, it might be a good job for you!

After doing the computer engineering lesson, read and answer the following questions. They serve as a guided exercise for you to identify and assess skills and interests of yours that might make computer engineering a good career for you.

STEP 7: CAREER REFLECTION EXERCISE

Start a Classroom Discussion

(Or have students complete the worksheet in Student Workbook)

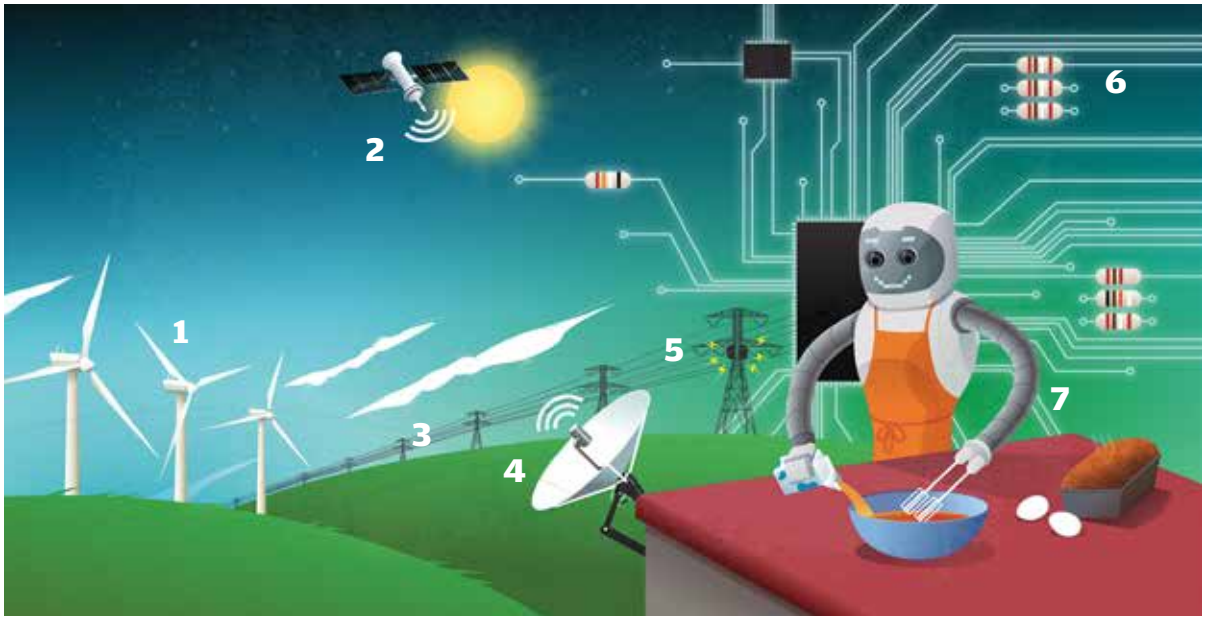
1. Think about what it felt like doing a computer engineering exercise. What parts, if any, did you enjoy? What parts did you not enjoy?

2. What skills do you think you used in completing your exercise? Write down as many as you can think of (shoot for at least 5, like math, reading, collaboration, imagination, art, measurement, and so on).

3. Looking back at this list of skills, pick the three you think you're best at. Which are the three hardest for you? How important do you think these skills would be in computer engineering? Why?

4. Can you think of anything you have seen or used or learned about that could have been designed by a computer engineer? What was it? How did it work? How can you imagine making it work better?

5. On a scale of 1-5, how much do you think you would like being a computer engineer, with 1 being a hole in the head and 5 being like cupcakes?



ELECTRICAL ENGINEERING

TEACH THE BASIC LEARNING EXERCISE

STEP 1 → Ask the students to turn to page 16 of "Dream, Invent, Create" and then read the rhyme aloud to the class. Or ask 3 different students to each read a stanza.

STEP 2 → Explain that this page is all about **electrical engineering**, and read the text around the border, which is also written out on the next page of this guide.

STEP 3 → Introduce the vocabulary from the electrical pages, by pointing out each image on the illustration. The numbers on the illustration correspond to the vocabulary on the next page of this guide.

STEP 4 → Then, start a Classroom Discussion (page 41), either verbally or as part of written assignment using the Student Workbook.

STEP 2: READ ALOUD THE TEXT AROUND THE BORDER

READ ALOUD

SO COOL Electrical engineers build machines and systems that transmit electricity from where it's produced to where it's used.

WHAT ELSE? Some also apply their know-how to computer systems and electronics, like designing new microchips to control robots, game consoles, or tablets.

SAVING THE PLANET Electrical engineers help develop wind turbines, solar cells, and other renewable energy technologies.

TELL ME MORE They might also design satellites and communication systems to send information around the world.

STEP 3: DISCUSS THE VOCABULARY AND CONCEPTS

READ ALOUD

Point out each image on the illustration and match it with the vocabulary below:

1. Wind turbine: A device that converts power from the wind into electricity. This energy is considered a renewable energy technology.

2. Satellite: It's a machine that is launched into space (by a rocket) and which moves around Earth in order to supply communications like TV, phone, and radio signals, navigation (GPS), or Earth observations, including weather.

3. Power lines: Wires that distribute electrical power across long distances. Overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy.

4. Communication dish: Imagine holding out your hand and catching words, pictures, and information passing by. That's more or less what this antenna device does: it catches radio waves and turns them into electrical signals feeding into something like a radio or television or a telephone system. Antennas like this are sometimes called receivers. A transmitter is a different kind of antenna that does the opposite job to a receiver: it turns electrical signals into radio waves so they

can travel sometimes thousands of miles around the Earth or even into space and back. Antennas and transmitters are the key to virtually all forms of modern telecommunication.

5. Transformer: An electrical device that transfers electrical energy between two or more circuits. The mighty power lines that criss-cross our countryside or wiggle unseen beneath city streets carry electricity at enormously high voltages from power plants to our homes.

6. Circuit board: Also known as a printed circuit board, or PCB, it's a thin board with a metal-coated surface, that has lines and pads that connect various points together. Etches are made in the metal with acid to create pathways for electricity to travel among various components. Just about every electronic appliance in your home contains a printed circuit board of some type: computers, printers, televisions, stereos, musical instrument amplifiers and synthesizers, digital clocks, microwave ovens, and cell phones.

7. Robot chef: While the chef in the illustration in *Dream, Invent, Create* is made-up, Moley Robotics has developed a real robot chef. Comprised of two robotic arms in a specially designed kitchen – which includes a stove top, utensils and a sink – the robot is able to reproduce the movements of a human chef in order to create a meal from scratch. The robot learns the movements after they are performed by a human chef, captured on a 3D camera and uploaded into the computer. The aim is to have professional chefs record themselves cooking their own recipes so that the robot will be able to mimic the techniques and replicate the dish.

STEP 4: START A CLASSROOM DISCUSSION

READ ALOUD

This can be done either verbally in the classroom or as part of a written assignment using the worksheet in the Student Handbook.

1. What are examples of electrical energy in our world? (Lightning; electrical charges moving through a wire or electricity; static electricity; batteries in use.)

2. When a storm causes the electricity in your home to go out, what do your parents do? What do you miss the most? What problems could it create? (Food going bad in freezer and refrigerator; house getting too hot or cold due to no air conditioning or heat, etc.)

3. Imagine all the things you see at home, in school, or anywhere else that get plugged into an electrical outlet. All those things are products of electrical engineering. Pick out two electrical devices you know of and describe what they do. Then imagine how you could make it do what it does even better. What kinds of changes and improvements can you imagine adding to the device? (Possible items: lamp, hair dryer, toaster oven, television.)

TEACH THE ADVANCED LEARNING EXERCISE

STEP 5 → After completing the basic learning exercise, use the introductory materials as read-aloud text or general background information to prepare students for the advanced exercise.

Do the **Design a Net-Zero Energy Classroom Exercise** with your students.

TEACH THE CAREER REFLECTION EXERCISE

STEP 6 → Read aloud and discuss the first two paragraphs together as a class.

Depending on your students' age or level of interest, share the information below about computer engineering careers:

- 10-year growth rate for electrical engineering jobs: 8.5%
- 10-year growth rate for jobs overall: 3.7%
- Median salary, 2019: $94,210
- Median individual salary overall, 2019: $40,100

STEP 7 → Students complete the Career Reflection Worksheet, with answers to serve as materials for further class discussions, as appropriate and feasible.

TRY THE EXTENSION ACTIVITY

STEP 8 → Ask the students to pick any of the vocabulary words and create a poster or write an essay, or research a real-life electrical engineer.

SOURCES: BUREAU OF LABOR STATISTICS, UNITED STATES CENSUS

STEP 5: ELECTRICAL ENGINEERING ADVANCED EXERCISE

Design a Net-Zero Energy Classroom

SUMMARY

Students create a concept design of their very own net-zero energy classroom by pasting renewable energy and energy-efficiency items into and around a pretend classroom on a sheet of paper. They learn how these items (such as solar panels, efficient lights, computers, energy meters, etc.) interact to create a learning environment that produces as much energy as it uses.

ENGINEERING CONNECTION

Engineers who understand how energy is used – and can create solutions to reduce energy use – in buildings are in high demand. Energy-efficient buildings are advantageous because they are more comfortable to inhabit and more environmentally-friendly, and they save in energy bills over the life of a building. More engineers are needed to design the next generation of buildings in our country – buildings that create as much energy as they use and conserve limited natural resources. Many schools have started to take advantage of the pleasant atmosphere, increased productivity, and cost savings associated with energy-efficient buildings by installing renewable energy systems and redesigning existing classrooms to use less energy.

LEARNING OBJECTIVES

After this activity, students should be able to:

- Explain how electrical energy is used in the classroom.
- Summarize how renewable energy can be harnessed on-site and used to power a building.
- List several ways how buildings can conserve energy and resources.

MATERIALS LIST

Each student needs:

- 1 set of the Net-Zero Energy Classroom Items
- 1 copy of the Net-Zero Energy Classroom Design Sheet
- Glue stick
- Scissors
- Colored pencils

WHAT DOES "NET-ZERO ENERGY" MEAN?

In the U.S., buildings consume about 40% of all energy that is used. Most of this energy is produced by coal plants that create a lot of pollution and cause environmental problems. Energy is used in buildings in a variety of ways.

Can you spot a few things in this classroom that use energy? It takes energy to heat and cool buildings so that we feel comfortable. We need energy for lights so we can see. Energy is used to power computers, TVs, fans and most electrical appliances. Essentially, everything we plug into the wall uses energy. We also use energy for cooking and other everyday tasks.

Can you imagine what life would be like without easy access to energy in our buildings, homes and schools? We need the ability to produce energy, but we also need to be environmentally responsible and wisely use the energy we have.

Can you imagine a building that actually generates as much energy as it uses? This is called a net-zero energy building. Homes, offices, stores and even schools can be net zero-energy buildings. Today we are going to redesign our classroom so that it is a net-zero energy classroom.

BACKGROUND READ ALOUD

The first step in designing a net-zero energy building – or in our case, a classroom – is to make sure that everything that uses energy does so wisely. Look around you: what do you see? Think of all the things you spot that use energy, and now think of ways that they could do it more efficiently. What are some ways we could use energy more efficiently in this classroom?

For example, we could put in compact florescent lights (CFLs), also known as the "squiggly bulbs," in all lamps and desk lights. These use one-quarter of the energy of traditional incandescent light bulbs because they do not heat up as much. In the ceiling, we could make sure that we have the most efficient fluorescent lighting. We can also replace lights with natural daylight. If we let natural light shine in from the outside through big windows or skylights, then we do not need to turn on as many lights in the classroom.

We can also use the light that shines in the windows to heat the classroom in the winter; this means we would not need to use the heaters as much. This is called passive solar heating. Locations that are sunny and have a colder climate, such as Colorado, are perfect for passive solar heating. To take advantage of the sun's warmth, windows need to be on the south side of a classroom because in the winter (in the Northern Hemisphere at least), the sun shines from the south. We can then put a curtain on the window or a shade above it outside to block the sun in the summer when it is higher in the sky and hotter in the classroom.

Once we are using energy wisely, we can place renewable energy technologies in our classroom to generate electricity and power our classroom. Who can name a form of renewable energy that we can harness right here at our school? Solar and wind are two very practical types of renewable energy that can be harnessed on-site and used to power anything that uses electricity. Lastly, we can add some other cool features to conserve water, recycle and help make our classroom sustainable in many ways. Let's get started!

WARM-UP EXERCISE

Brainstorming: As a class, have students engage in finding the major energy-using items in their classroom. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas, and discourage criticism of ideas. Have them raise their hands to respond. Write their ideas on the board.

Class Discussion: Ask a discussion question to get students to think about the upcoming activity. After soliciting answers, explain that these questions will be answered during the activity.

Ask students what they already know about solar panels and wind turbines, such as where outside they should be placed and why.

Have students discuss the list generated during brainstorming. Ask students to think about how any of the listed items could use energy more efficiently.

BEFORE THE ACTIVITY

1. Print the Net-Zero Energy Classroom Items and cut them so that each group/student has one set. If you have shorter class periods then it may be more practical to cut the items out in advance and presort them for each group.

2. Print the Net-Zero Energy Classroom Design Sheet (one for each group/student).

WITH THE STUDENTS

1. Give each group or student a Net-Zero Energy Classroom Design Sheet and a set of Net-Zero Energy Classroom Items.

2. Pass out scissors and glue sticks.

3. Instruct the students to place all of their Net-Zero Energy Classroom Items inside the classroom in the locations they think would be most appropriate,

and to draw in windows and other doors or lights, etc. There are some common item placements:

Inside: Computers, lights, heater/AC, digital display, recycle bin.
Outside: Compost bin, water storage tank (pipe should flow from roof to tank), bike rack, energy meter (attached to side of building), solar panels (on roof), wind turbine (on roof or far away from side of building).

4. Students should also draw windows in the wall of the classroom.
5. Have students label all items they have placed in the classroom. Indicate North direction on the map.
6. Have students color their classroom.
7. Have students write a sentence or two that explains why they have placed each item where they did.

Optional: Have students draw wires that connect the renewable energy items to the energy meter and then from the meter to the items in the classroom that use energy. (Wires should go to the energy meter before going to lights and computers.) Students can also draw wires to the power lines and utility.

Optional: Have students include other items in their design that might be used around the inside or outside of the classroom, including gardens, rain being trapped by gutters and flowing to a storage tank, bicycles or scooters, desks and chairs, etc.

TROUBLESHOOTING TIPS

Students may put things in places that don't make sense, so stroll around and observe how each student is doing and guide them as necessary. (See step #3 under Procedures for correct placement of items.)

INVESTIGATING QUESTION

What is thrown away in your classroom that could be recycled? (Lightbulbs, paper, boxes, paper lunch bags, milk boxes, etc)

ASSESSMENT

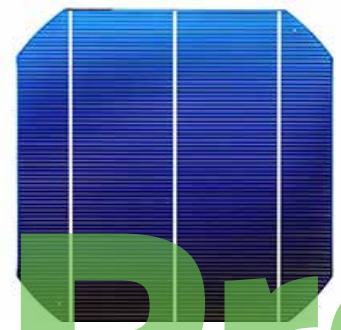
Activity Embedded Assessment

Zero-Energy Classroom Design Sheet: Allow students to place all of their classroom items on their classroom design sheets in order to design their net-zero energy classrooms. Students should be able to correctly place these items either inside or outside of the classroom space. If drawing wires and connections, students should be able to connect the classroom items in a proper way. Observe the students' progress and ask them (individually) to explain why they are putting an item in a certain place and how it works.

Net-Zero Energy Items with labels

GENERATING POWER

Photovoltaic Solar Cells



Wind Power Turbine

EFFICIENTLY USING POWER

Air Conditioning/Heating

Computer

Compact Fluorescent Light Bulb

MONITORS AND CONTROLS

Smart Electricity Meter

Programmable thermostat

Net-Zero Energy Items with Labels (cont.)

WATER CONSERVATION

Water Storage Tank

REDUCING WASTE

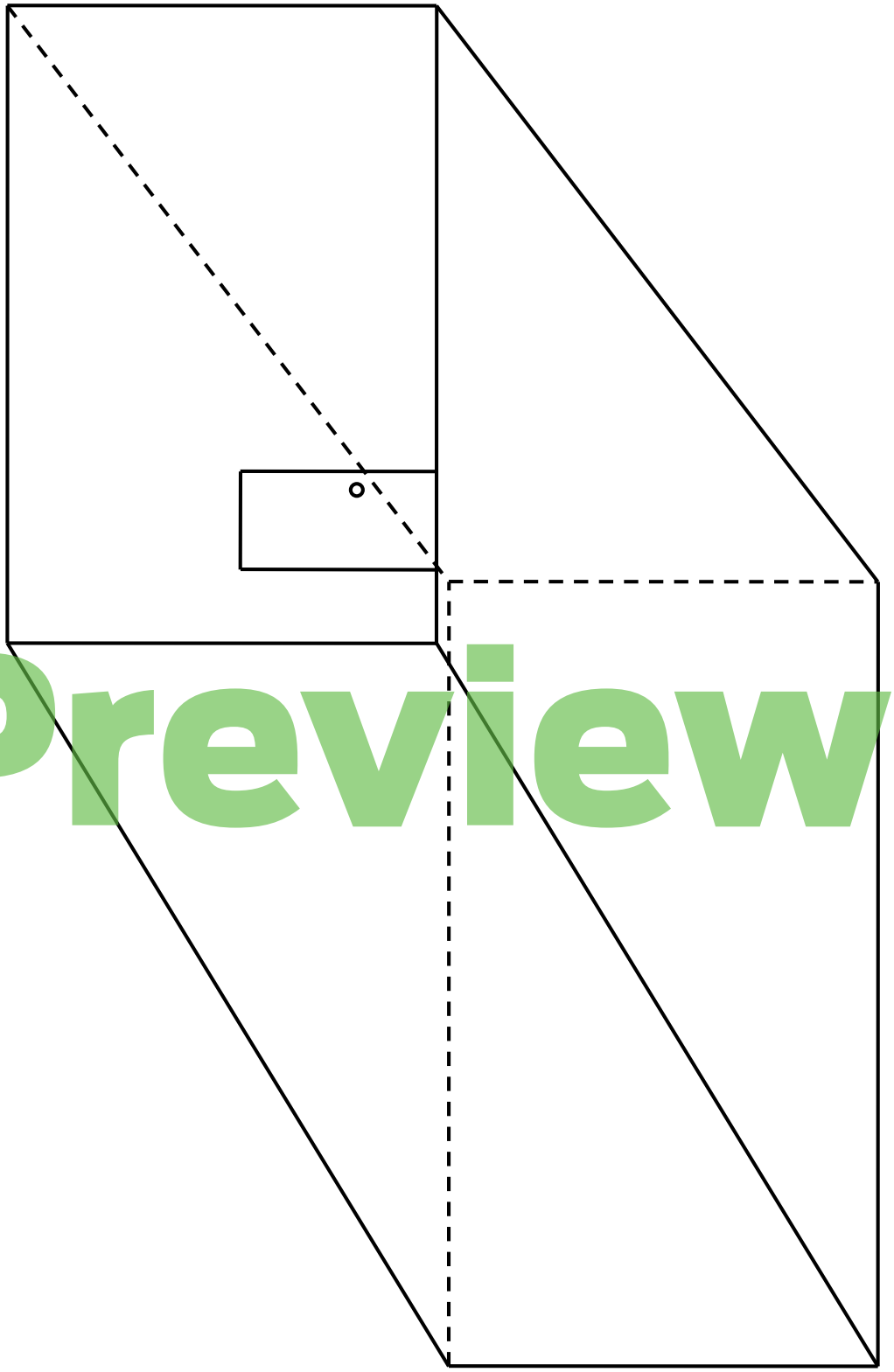
Recycling bin

Compost bin

CONSERVING ENERGY

Bike rack

Net - Zero Energy Classroom



ELECTRICAL ENGINEERING ADVANCED EXERCISE

STEP 6: CAREER REFLECTION EXERCISE READ ALOUD

Discuss Electrical Engineering Careers

What do electrical engineers do?

Electrical engineers design, develop, test, and supervise the manufacture of electrical equipment, products, and tools.

Is this a good job?

A good job is one that you like to do and that connects with your skills, interests, and values. You should also think about what kind of need exists for people to do jobs that might appeal to you.

The need for electrical engineers is expected to increase more than for most other jobs over the next ten years. And the typical salary for electrical engineers is over two times greater than the typical salary for jobs overall. So if you like what you're learning about electrical engineering, it might be a good job for you

After doing the electrical engineering lesson, read and answer the following questions. They serve as a guided exercise for you to identify and assess skills and interests of yours that might make electrical engineering a good career for you.

STEP 7: CAREER REFLECTION EXERCISE

Start a Classroom Discussion

READ ALOUD

(Or have students complete the worksheet in Student Workbook)

1. Think about what it felt like doing an electrical engineering exercise. What parts, if any, did you enjoy? What parts did you not enjoy?

2. What skills do you think you used in completing your exercise? Write down as many as you can think of (shoot for at least 5, like math, reading, collaboration, imagination, art, measurement, and so on).

3. Looking back at this list of skills, pick the three you think you're best at. Which are the three hardest for you? How important do you think these skills would be in electrical engineering? Why?

4. Can you think of anything you have seen or used or learned about that could have been designed by an electrical engineer? What was it? How did it work? How can you imagine making it work better?

5. On a scale of 1-5, how much do you think you would like being an electrical engineer, with 1 being a hole in the head and 5 being like cupcakes?

ENVIRONMENTAL ENGINEERING

TEACH THE BASIC LEARNING EXERCISE

STEP 1 → Ask the students to turn to page 18 of "Dream, Invent, Create" and then read the rhyme aloud to the class. Or ask 3 different students to each read a stanza.

STEP 2 → Explain that this page is all about **environmental engineering**, and read the text around the border, which is also written out on the next page of this guide.

STEP 3 → Introduce the vocabulary from the environmental pages, by pointing out each image on the illustration. The numbers on the illustration correspond to the vocabulary on the next page of this guide.

STEP 4 → Then, start a Classroom Discussion (page 59), either verbally or as part of written assignment using the Student Workbook.

STEP 2: READ ALOUD THE TEXT AROUND THE BORDER

READ ALOUD

SO COOL Environmental engineers devise solutions to problems that face our air, plants, soil, and water.

WHAT ELSE? They design systems to prevent and control pollution, conserve the earth's resources, and slow down global climate change.

SAVING THE PLANET Environmental engineers are working on new ways to collect and sort waste so that more of it can be recycled.

TELL ME MORE They might also learn about the law and public policy to figure out environmental solutions that benefit all parts of society.

STEP 3: DISCUSS THE VOCABULARY AND CONCEPTS

READ ALOUD

Point out each image on the illustration and match it with the vocabulary below:

1. Recycling: A process to convert trash and waste materials into new products. Recycling prevents waste of potentially useful materials, reduces the consumption of fresh raw materials, reduces energy usage, reduces air pollution (from burning waste) and water pollution (from land filling).

2. Clean air and land: These are main goals of environmental engineers, who want to protect the Earth's natural resources. They are constantly trying to find ways to reduce air pollution, and clean up the environment.

3. Water treatment plant: Within these enormous buildings engineers remove water contaminants (or reduce their concentration) so that the water becomes fit for drinking, use by industry, or returning to the environment.

4. Clean water: Clean water is essential to all life, yet 1 in 10 people (780 million) lack access to clean water. Contaminated water causes deadly diseases, so clean water for the world is a big goal of environmental engineers.

ADDITIONAL VOCABULARY FROM THE LESSON

City planning: City planning is an approach to make sure a new community is well planned with appropriate zoning, and environmental and public health protections.

Emissions: Emissions are waste substances released into the air or water.

Environmentalist: A person who advocates or works to protect the air, water, animals, plants, and other natural resources from destruction and/or pollution.

Natural resource management: The planning and use of natural resources (land, water, soil, plants, and animals) with special attention to long-term quality of life for people and the environment.

Sustainability: Sustainability is meeting the needs of the present without compromising the ability of future generations to meet their own needs. Engineering sustainability is considering the needs of the future in the designs of today.

Trade-offs: An exchange of one thing in return for another, especially giving up of one benefit or advantage for another regarded as more desirable.

STEP 4: START A CLASSROOM DISCUSSION

READ ALOUD

This can be done either verbally in the classroom or as part of a written assignment using the worksheet in the Student Handbook.

1. Do you think factories affect the environment? If yes, is it in a good way or a bad way? Could we get rid of factories altogether? Why or why not? (Factories pollute and are responsible for nearly two-thirds of the emissions to blame for global climate change. But they are a necessary element of modern society, producing computers, airplanes, cars, clothing, furniture, and toys.

2. Does your family recycle? What about your school? Why do you think this is important? (Recycling reduces the amount of waste sent to landfills and incinerators, conserves natural resources, and saves energy since fewer items will need to be manufactured.)

3. Why is conservation of our natural resources important? (There is a limited amount of our natural resources like water and trees. We need to protect them so they are there for future generations.)

4. Think about the trees, the soil, and any bodies of water (streams, rivers, lakes, ocean, etc.) near where you live. Which one do you think is most at risk of being polluted? What can you imagine doing to protect all these natural resources in your area safer for people to live with and use?

TEACH THE ADVANCED LEARNING EXERCISE

STEP 5 → After completing the basic learning exercise, use the introductory materials as read-aloud text or general background information to prepare students for the advanced exercise.

Do the **Engineers Speak for the Trees** exercise with your students.

TEACH THE CAREER REFLECTION EXERCISE

STEP 6 → Read aloud and discuss the first two paragraphs together as a class.

Depending on your students' age or level of interest, share the information below about environmenal engineering careers:

- 10-year growth rate for environmental engineering jobs: 8.3%
- 10-year growth rate for jobs overall: 3.7%
- Median salary, 2019: $88,860
- Median individual salary overall, 2019: $40,100

STEP 7 → Students complete the Career Reflection Worksheet, with answers to serve as materials for further class discussions, as appropriate and feasible.

TRY THE EXTENSION ACTIVITY

STEP 8 → Ask the students to pick any of the vocabulary words and create a poster or write an essay, or research a real-life environmental engineer.

STEP 5: ENVIRONMENTAL ENGINEERING ADVANCED EXERCISE

Engineers Speak for the Trees Activity

SUMMARY

Students begin by reading Dr. Seuss's *The Lorax* as an example of how overdevelopment can cause long-lasting environmental destruction. Students discuss how to balance the needs of the environment with the needs of human industry.

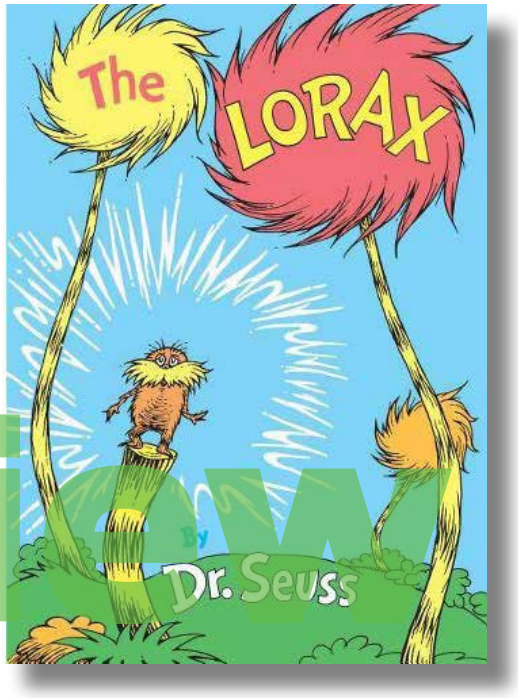
Dr. Seuss's book, *The Lorax*, has become a popular metaphor when speaking of the impact of human industry on its environment. Building on this story, students learn about city planning and how a variety of types of engineers work together to design and build a new city. Students learn that the fourth law of ecology, "there is no such thing as a free lunch," extends beyond the natural world and into the engineered world. Use this activity as a wrap up of an introduction to engineering and/or an Earth Day activity.

The Four Laws of Ecology by physicist and ecologist Barry Commoner:

1. Everything is connected to everything else.
2. Everything must go somewhere.
3. Nature knows best.
4. There is no such thing as a free lunch.

ENGINEERING CONNECTION

Engineers are involved in both the creation of the human-built environment – through the design of factories, housing, roads and bridges – as well as the protection of the natural environmentthrough resource management, city planning and sustainable building practices.



LEARNING OBJECTIVES

After this activity, students should be able to:

- Describe how engineers protect the environment through reducing pollution, protecting natural resources, and creative city planning.
- Explain that city planning involves balancing human and environmental needs.

MATERIALS LIST

- *The Lorax* by Dr. Seuss (book) and/or *The Lorax* (video; available at most public libraries; runs 25 minutes; play either in lieu of reading the book aloud to the class, or while students are doing the drawing portion of the activity).

WHAT DO ENVIRONMENTAL ENGINEERS DO? READ ALOUD

You may know that engineers are responsible for much of the "built environment," including roads, bridges, buildings, skyscrapers, cars, airplanes, and so forth, but did you know that engineers also help keep the natural environment safe and healthy? The responsibilities of many types of engineers ensure both public and environmental health. Their jobs are to balance human and environmental needs.

ENVIRONMENTAL ENGINEERING ADVANCED EXERCISE

Would you want to live in a world without trees, fresh air, birds, or barbaloots? What about a world without clean drinking water, warm houses, cars, and roller coasters? Engineers have a big responsibility in how they use technology. Today, we are going to begin a project to plan a new town. To start, we are going to read *The Lorax*, a story by Dr. Seuss. This story shows us what can happen when the needs of the environment are not taken into consideration. Then, we will do an exercise in city planning. City planning is the activity of determining the future physical arrangement and condition of a community. This involves examining the present condition, forecasting future requirements, creating a plan to fulfill these requirements, and securing proposals (construction, legal, financial) to implement the plan.

WARM-UP EXERCISE

READ ALOUD

Open Discussion: Introduce the topic and gauge students' knowledge base by asking them the following questions:

1. Do you think factories affect the environment? If yes, is it in a good way or a bad way?
2. Could we get rid of factories all together? Why or why not?
3. Drawing: Ask students to draw pictures of factories. Have them label possible sources of pollution from the factory. Share some of the pictures with the class.

WITH THE STUDENTS, PART 1: What's the Story?

READ ALOUD

Read aloud to the class (or show the video of) Dr. Seuss's *The Lorax*.

Use the following questions to lead a class discussion:

1. Who is the Lorax? Who does he represent in the real world? (Answer: The Lorax is one of the main characters in the book and he "speaks for the trees." The Lorax represents environmentalists.)

2. Who is the Once-ler? Who does he represent in the real world? (Answer: The Once-ler is another one of the main characters and he develops an industry selling thneeds. The Once-ler represents industries and factories that are not environmentally friendly.)

3. Why is the Once-ler called the Once-ler? (Answer: The Once-ler only uses things once.) What is a thneed? Would you want one? Why or why not? (Answer: Students may come up with all of the ways you can use thneeds, as mentioned in the book. Talk about how some products are very useful and we need them, but not without some limitations about how many should be made, etc.)

4. What happens after the Once-ler sets up his thneed factory? (Answer: The area is slowly destroyed by pollution. All of the animals leave and the once-beautiful truffula forest is left in ruins.)

5. Where do all the animals go? Why do they leave? (Answer: The animals go off to different places in search of a healthier and safer environment. The pollution from the thneed factory forces them to leave.)

6. What happens when the last truffula tree is chopped down? (Answer: The thneed factory closes down and the Once-ler's family leaves. The Once-ler finally sees what he has done to the natural area.)

7. Ask students to imagine that they are the child in the story and have just been given the last truffula seed and a big job to help plant replant the truffula forest.

8. How long does it take for a healthy forest to grow back? Discuss students' ideas. Ask them to think of ways to prevent the forest from becoming depleted in the first place.

9. Remind students that engineers are involved in city planning, from designing the buildings and roads, as well as how many and where to place them so as to reduce harmful environmental impacts. Ask students if they think they could design a town in which truffula trees and Once-lers and loraxes and they (!) could all live together.

WITH THE STUDENTS, PART 2: Building YourTown

1. Explain to students that they will be serving as City Council Members given the job of designing a new town for all their families and friends to live in: YourTown, USA. Everyone they know is going to be moving there.

2. Students will be asked to design the town and make choices about allocating resources among the four areas of goods and services that people will need in order to live in YourTown:

   - **Selling/making things**
     All the things we need to make and buy for daily life.
   - **Living/learning**
     Buildings and facilities where we live, go to school, eat, and entertain ourselves.
   - **Playing/gathering**
     Places we gather, exercise, enjoy the outdoors.
   - **Powering/managing**
     The energy and services we need to make life in YourTown possible and sustainable.

3. As a class, lead a discussion in which the class ranks these four areas from most to least important. Write the list on the board or someplace in view for later reference.

4. As a class, students will work together to design a town that includes developing sustainable resources in all these four areas.

5. Use the table below to show your students the four levels of development in each area, along with the costs associated with each level. Explain clearly that each successive level includes all the goods shown above it in the same

column. For example, spending $4 on Selling/making would buy video games for YourTown residents as well as all the goods in the $1, $2, and $3 boxes

Cost	Selling/ making	Living/ learning	Playing/ gathering	Powering/ managing
$1	Food, clothing	Apartments, houses	Parking lots	Electricity and heat
$2	Cars, furniture	Stores with basic stuff, schools	Some parks, playgrounds	Trash pickup, clean water, telephones
$3	Toys, sports equipment	Stores with fun stuff, movie theaters, restaurants	Many nice parks, playgrounds	Recycling, cable TV, internet, expensive health care
$4	Video games	Amusement parks	Hiking/biking trails, ball fields	Free health care

6. Explain that students will be divided up into four groups, with each group responsible for designing and defending development in one of these four areas.

7. But here's the catch:

   - To develop YourTown so that it can offer everything for everybody would cost $16.
   - The City Council of YourTown (the whole class) has a limited budget, with only $11 to spend on building and running the city.

8. Students take 10 minutes in their groups to make an argument to present to the class about why the city should spend money on their area.

9. Groups present their arguments to the class.

10. Lead a discussion with the whole class about how to spend the $11 available for developing and running YourTown, with votes as necessary to make final decisions. Remind students of the ranked list of goods and services that they decided on before dividing into groups. Review the list, discuss any possible revisions to the list, and consider how/if this list helps resolve disagreements about how to arrive at a final agreement on allocating the town's $11 budget.

EXTENSION ACTIVITY

The City Council of YourTown also manages the Dessert Fund, used to buy dessert every day for the family of every student in your class. Dessert every day costs $1/year for 5 families, and the City Council buys dessert for everyone. The City Council can also borrow money from the dessert fund to pay for goods and services.

But that would mean some students' families would not get dessert. For a whole year! Dessert is available only through the City Council Dessert Fund and cannot be bought with families' own money. If students wish to pay for more goods and services than their $11 budget can cover, they must take money out of the dessert fund. That means members of the class must identify 5 families to go without dessert for every dollar they wish to use to pay for more goods and services for the town. Enjoy!

POST-ACTIVITY DISCUSSION

Once your class settles on a final budget, lead a discussion reflecting on how you reached a decision. What do the necessary tradeoffs reveal about these kinds of values the budget reflects? What did it feel like for students to give up some goods and services in exchange for others? What kinds of changes to laws, practices, or behaviors could they imagine that would allow for a different kind of governing and budgeting situation?

STEP 6: CAREER REFLECTION EXERCISE READ ALOUD

Discuss Environmental Engineering Careers

What do environmental engineers do?

Environmental engineers use the principles of engineering, soil science, biology, and chemistry to develop solutions to environmental problems.

Is this a good job?

A good job is one that you like to do and that connects with your skills, interests, and values. You should also think about what kind of need exists for people to do jobs that might appeal to you. The need for environmental engineers is expected to increase more than for most other jobs over the next ten years. And the typical salary for environmental engineers is over two times higher than the typical salary for jobs overall. So if you like what you're learning about environmental engineering, it might be a good job for you!

After doing the environmental engineering lesson, read and answer the following questions. They serve as a guided exercise for you to identify and assess skills and interests of yours that might make environmental engineering a good career for you.

STEP 7: CAREER REFLECTION EXERCISE

Start a Classroom Discussion

READ ALOUD

(Or have students complete the worksheet in Student Workbook)

1. Think about what it felt like doing an environmental engineering exercise. What parts, if any, did you enjoy? What parts did you not enjoy?

2. What skills do you think you used in completing your exercise? Write down as many as you can think of (shoot for at least 6, like math, reading, collaboration, imagination, measurement, daydreaming, and so on).

3. Looking back at this list of skills, pick the three you think you're best at. Which are the three hardest for you? How important do you think these skills would be in environmental engineering? Why?

4. Can you think of anything you have seen or used or learned about that could have been designed by an environmental engineer? What was it? How did it work? How can you imagine making it work better?

5. On a scale of 1-5, how much do you think you would like being an environmental engineer, with 1 being a hole in the head and 5 being like cupcakes?

NEXT GENERATION SCIENCE STANDARDS FOR ACTIVITIES

BIOMEDICAL ENGINEERING ACTIVITY, Biomimicry: Natural Designs, page 16

- Make observations of plants and animals to compare the diversity of life in different habitats. (Grade 2)
- Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. (Grades 3 - 5)
- Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. (Grade 4)

ADAPTED FROM: https://www.teachengineering.org and http://www.kidsciencechallenge.com/

COMPUTER ENGINEERING ACTIVITY, **Robotic Cups**, page 30

- Practices: Asking questions and defining problems; communicating solutions.
- Defining and delimiting engineering problems; develop a model to generate data for iterative testing and modification of a proposed object, tool, or process to achieve optimal design.

ADAPTED FROM: https://csedweek.org/files/CSEDrobotics.pdf

ELECTRICAL ENGINEERING LESSON, Design a Net-Zero Energy Classroom, page 46

- Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. (Grades 3 - 5)
- Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. (Grade 4)
- Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. (Grade 5)
- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. (Grades 6 - 8)

ADAPTED FROM: https://www.teachengineering.org

ENVIRONMENTAL ENGINEERING LESSON, Engineers Speak for the Trees, page 64

- Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. (Grades 3 - 5)
- Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. (Grade 5)

ADAPTED FROM: https://www.teachengineering.org